Electronic Version
Stylesheet Version v1.1.1

Claims

[c1] 1. An inline sensing unit for a fluid delivery system comprising a fluid source, the sensing unit comprising:
a housing comprising an inlet for receiving a fluid from the fluid source, an outlet for discharging the fluid from the housing, and at least one cavity between the inlet and the outlet;
a sensing element mounted within the at least one cavity of the housing, the sensing element having a first response to the density of the fluid flowing between the inlet and the outlet of the housing, the sensing element having a second response to the mass flow rate of the fluid flowing between the inlet and the outlet of the housing;
electronic circuitry within the at least one cavity of the housing, the electronic circuitry producing an electrical output based on at least one of the first and second responses of the sensing element; and
means for providing communication between the electronic circuitry and an electronic device remote from the housing.

[c2] 2. The inline sensing unit according to claim 1, wherein

the sensing element comprises:

a freestanding tube portion through which the fluid flows;

means for vibrating the freestanding tube portion at a resonant frequency thereof that varies with the density of the fluid flowing therethrough, the resonant frequency of the freestanding tube portion being the first response of the sensing element, the Coriolis effect causing the freestanding tube portion to twist to a degree that varies with the mass flow rate of the fluid flowing therethrough while the freestanding tube portion is vibrated at resonance, the degree of twist being the second response of the sensing element; and

means for sensing movement of the freestanding tube portion to sense the resonant frequency and the degree of twist of the freestanding tube portion as the fluid flows therethrough.

[c3] 3. The inline sensing unit according to claim 1, wherein the electrical output of the electronic circuitry is a volumetric flow rate output based on the volumetric flow rate of the fluid flowing through the housing determined from the first and second responses of the sensing element, and at least one of the electronic circuitry and the electronic device comprises means for measuring elapsed time during which the fluid has flowed through

the housing.

[c4] 4. The inline sensing unit according to claim 3, the sensing unit further comprising means disposed within the housing for stopping flow of the fluid through the housing in response to the elapsed time measured by the measuring means and the volumetric flow rate output of the electronic circuitry.

[c5] 5. The inline sensing unit according to claim 3, wherein the fluid source comprises means for flowing the fluid through the housing at a first flow rate and then subsequently at a higher second flow rate, the flowing means being controlled by the electronic device based on the elapsed time measured by the measuring means.

[c6] 6. The inline sensing unit according to claim 1, further comprising means on the housing for displaying a visual output based on the electrical output of the electronic circuitry.

[c7] 7. The inline sensing unit according to claim 1, further comprising means on the housing for producing an audible output based on the electrical output of the electronic circuitry.

[c8] 8. The inline sensing unit according to claim 1, wherein the fluid source is a manually-operated, handheld sy-

ringe to which the housing is mounted.

[c9] 9. The inline sensing unit according to claim 8, further comprising a hypodermic needle mounted to the outlet of the housing.

[c10] 10. The inline sensing unit according to claim 1, further comprising means associated with at least one of the inlet and the outlet of the housing for coupling an intravenous tube thereto.

[c11] 11. The inline sensing unit according to claim 1, further comprising means associated with the outlet of the housing for coupling an accessory to the outlet, the accessory being selected from the group consisting of hypodermic needles, catheters, cannula, and septums.

[c12] 12. The inline sensing unit according to claim 1, wherein the electrical output of the electronic circuitry is a density or specific gravity output based on the density of the fluid flowing through the housing determined from the first response of the sensing element.

[c13] 13. The inline sensing unit according to claim 12, the sensing unit further comprising means disposed within the housing for stopping flow of the fluid through the housing in response to the density output of the electronic circuitry.

[c14] 14. The inline sensing unit according to claim 1, wherein the housing comprises first and second housing members, first and second cavities of the at least one cavity being defined in the first and second housing members, respectively, the first housing member containing all elements of the sensing unit that contact the fluid, the second housing member containing elements of the sensing unit that do not contact the fluid, wherein the first housing member constitutes a disposable portion of the housing and the second housing member constitutes a separable reusable portion of the housing.

[c15] 15. The inline sensing unit according to claim 14, the sensing unit further comprises means disposed within the second housing member for stopping flow of the fluid through the housing in response to the electrical output of the electronic circuitry.

[c16] 16. The inline sensing unit according to claim 14, further comprising means disposed in the second housing member for displaying a visual output based on the electrical output of the electronic circuitry.

[c17] 17. The inline sensing unit according to claim 14, further comprising means disposed in the second housing member for producing an audible output based on the

electrical output of the electronic circuitry.

[c18] 18. An infusion system comprising a fluid source and an inline sensing unit, the sensing unit comprising:
a housing comprising an inlet for receiving a fluid from the fluid source, an outlet for discharging the fluid from the housing, and at least one cavity between the inlet and the outlet;
a sensing element mounted within the at least one cavity of the housing, the sensing element comprising:
a freestanding tube portion through which the fluid flows;
means for vibrating the freestanding tube portion at a resonant frequency thereof that varies with the density of the fluid flowing therethrough, the Coriolis effect causing the freestanding tube portion to twist to a degree that varies with the mass flow rate of the fluid flowing therethrough while the freestanding tube portion is vibrated at resonance; and
means for sensing movement of the freestanding tube portion to sense the resonant frequency and the degree of twist of the freestanding tube portion as the fluid flows therethrough;
electronic circuitry within the at least one cavity of the housing, the electronic circuitry producing an electrical output based on the density and the mass flow rate of

the fluid flowing through the sensing element, the electrical output comprising at least one of specific gravity, dose, dose rate, and volume of the fluid delivered through the sensing element;

means for providing communication between the electronic circuitry and an electronic device remote from the housing;

means disposed within the housing for stopping flow of the fluid through the housing in response to the electrical output of the electronic circuitry; and

means on the housing for displaying a visual output based on the electrical output of the electronic circuitry.

[c19] 19. The infusion system according to claim 18, wherein the fluid source is a manually-operated, handheld syringe to which the housing is mounted, the sensing unit further comprising a hypodermic needle mounted to the outlet of the housing.

[c20] 20. The infusion system according to claim 18, wherein the housing comprises first and second housing members, the inlet, the outlet and the at least one cavity containing the sensing element being disposed in the first housing member, the electronic circuitry, the communication providing means, the flow stopping means, and the display means being disposed in the second housing member, wherein the first housing member constitutes a

separable disposable portion of the housing and the second housing member constitutes a separable reusable portion of the housing.

[c21] 21. An infusion system comprising:
an intravenous pole;
an intravenous tube hanging alongside the intravenous pole;
an inline sensing unit coupled to the intravenous tube and comprising a housing, an inlet for receiving a fluid from the intravenous tube, an outlet for discharging the fluid from the housing, at least one cavity between the inlet and the outlet, and a sensing element mounted within the at least one cavity, the sensing element having a first response to the density of the fluid flowing between the inlet and the outlet of the housing, the sensing element having a second response to the mass flow rate of the fluid flowing between the inlet and the outlet of the housing;
a module attached to the intravenous pole, the module comprising electronic circuitry that produces an electrical output based on at least one of the first and second responses of the sensing element, means for displaying a visual output based on the electrical output of the electronic circuitry, and means for producing an audible output based on the electrical output of the electronic

circuitry;

means for providing communication between the sensing unit and the module;

means in communication with the module for stopping flow of the fluid through the intravenous tube in response to the electrical output of the electronic circuitry; and

a computer remote from the module and coupled to the module for communication therewith.

[c22] 22. The infusion system according to claim 21, wherein the sensing element comprises:

a freestanding tube portion through which the fluid flows;

means for vibrating the freestanding tube portion at a resonant frequency thereof that varies with the density of the fluid flowing therethrough, the resonant frequency of the freestanding tube portion being the first response of the sensing element, the Coriolis effect causing the freestanding tube portion to twist to a degree that varies with the mass flow rate of the fluid flowing therethrough while the freestanding tube portion is vibrated at resonance, the degree of twist being the second response of the sensing element; and

means for sensing movement of the freestanding tube portion to sense the resonant frequency and the degree

of twist of the freestanding tube portion as the fluid flows therethrough.

[c23] 23. The infusion system according to claim 21, wherein the module does not contain components that contact the fluid, the sensing unit constitutes a separable disposable portion of the infusion system, and the module constitutes a reusable portion of the infusion system.

[c24]